

**DATA QUALITY SUMMARY REPORT
FOR AETHALOMETER 7-WAVELENGTH
BLACK CARBON DATA COLLECTED BY SONOMA
TECHNOLOGY, INC., DURING THE CALIFORNIA
REGIONAL PM₁₀/PM_{2.5} AIR QUALITY STUDY**

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1. INTRODUCTION AND OBJECTIVES

The purpose of this Data Quality Summary Report is to provide data users with an understanding of the quality of black carbon (BC) data collected by Sonoma Technology, Inc. (STI) for the California Regional PM₁₀/PM_{2.5} Air Quality Study (CRPAQS). **Table F-1** summarizes the operating sites and times for aethalometer measurements in CRPAQS. The 7-wavelength aethalometer reports PM_{2.5} BC concentrations ($\mu\text{g}/\text{m}^3$) at seven wavelengths on a 5-minute basis in standard temperature and pressure (STP). Wavelengths were at 350 (ultraviolet-UV), 450 (blue), 571 (green), 590 (blue), 660 (red), 880 (near infrared-NIR), and 950 (NIR) nm. The 5-minute data were also averaged to 60-minute concentrations. This statement provides summary information on data completeness, lower quantifiable limit (LQL), accuracy, and precision. Data completeness was calculated for all sites based on data delivered to ARB; the start date/time indicates the beginning of valid data, continuous until the stop date/time. Data validation suggested that all aethalometer instruments performed similarly; thus, Angiola was used as a representative site to calculate LQL, accuracy, and precision for all aethalometers operated by STI in the study.

Table F-1. Location and duration of aethalometer 7-wavelength measurements performed by STI during CRPAQS.

Site	Start Date/Time	Stop Date/Time
Angiola Trailer	10/26/00 12:50 PST	2/28/01 23:55 PST
Angiola 100-m Tower	12/1/00 16:20 PST	2/16/01 17:00 PST
Bakersfield	10/23/00 16:30 PST	2/14/01 23:55 PST
Bethel Island	11/17/00 16:05 PST	2/15/01 5:55 PST
Corcoran	9/13/00 11:50 PST	11/14/00 23:55 PST
Edwards	6/20/00 16:50 PST	9/1/00 8:45 PST
Sacramento Del Paso	10/6/00 11:00 PST	2/9/01 23:55 PST
San Jose	10/4/00 12:50 PST	2/9/01 12:30 PST
Sierra Nevada Foothills	11/19/00 18:00 PST	2/14/01 14:20 PST

Several other documents are available from which to obtain information about the CRPAQS field study and data processing. Sampling locations are described in Wittig et al. (2003). Quality control screening procedures are summarized by Hafner et al. (2003). Results of systems and performance audits and intercomparisons are provided by Bush et al. (2001).

The data quality objectives (DQOs) for the 7-wavelength aethalometer BC from instrument specifications are shown in **Table F-2**. A DQO for completeness was not available. The instrument specification DQO for accuracy could not be tested. The 60-minute data met the DQO for LQL at all wavelengths while only the 660 nm 5-minute data met the LQL DQO. The 5-minute data at all wavelengths met the DQO for precision while the 60-minute data did not.

Table F-2. Data quality objectives for aethalometer 7-wavelength data collected during CRPAQS.

Data Quality Metric	Objective
Lower Quantifiable Limit	0.035 $\mu\text{g}/\text{m}^3$
Accuracy	0.035 $\mu\text{g}/\text{m}^3$
Precision	0.035 $\mu\text{g}/\text{m}^3$

2. DATA COMPLETENESS

Data completeness for aethalometer 7-wavelength sites is shown in **Tables F-3 through F-11**. Data capture quantifies the percentage of total records received versus the number expected during the “period of operation” defined by the start and stop dates/times in Table F-1; the start date/time is the first instance of valid data, and the period of operation is continuous until the stop date/time. The number of valid data points is divided by the number of captured data points to calculate the data recovery. Validity is defined for this calculation as any data point that has a quality control flag of V0 (valid) or V1 (valid but comprised wholly or partially of below-MDL data). Details of data validation are included in Hafner et al. (2003). For some of the sites, the information for several wavelengths was nearly identical; thus, the data records were combined. In these cases, the numbers of records are per wavelength.

Table F-3. Seven-wavelength aethalometer BC data completeness values for the Angiola Trailer.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-660	36,134	36,134	100%	24,984	69%	1165	2962	7023
5-min	880	36,134	36,134	100%	27,504	76%	1177	2987	4466
5-min	950	36,134	36,134	100%	24,968	69%	1180	2963	7023
60-min	370-660	3012	3012	100%	2237	74%	87	316	372
60-min	880	3012	3012	100%	2450	81%	87	321	154
60-min	950	3012	3012	100%	2237	74%	87	316	372

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates ranged from 69% (most wavelengths, 5-min) to 81% (880 nm wavelength, 60-minute). Data recovery rates for the aethalometer were influenced by the length and frequency of tape transfer. Tape transfer was dependent on the combination of instrument model, use/disuse of the tape-saver function, data acquisition system software version, and particle loading on the tape. Other factors in

lowering the data recovery rates included instrument flow problems, instrument maintenance, and power outages; details are provided in the data management report (Hafner et al., 2003)

Table F-4. Seven-wavelength aethalometer BC data completeness values for the Angiola 100-meter Tower.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-520	22,185	22,185	100%	15,755	71%	2	4517	1911
5-min	590	22,185	22,185	100%	15,630	70%	127	4517	1911
5-min	660-950	22,185	22,185	100%	15,756	71%	1	4517	1911
60-min	370-520	1850	1850	100%	1422	77%	2	418	8
60-min	590 nm	1850	1850	100%	1377	74%	47	418	8
60-min	660-950	1850	1850	100%	1423	77%	1	418	8

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 70% (5-minute) to 77% (60-minute).

Table F-5. Seven-wavelength aethalometer BC data completeness values for Bakersfield.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-950	32,922	32,922	100%	25,260	77%	4323	278	3061
60-min	370-950	2744	2744	100%	2301	84%	386	49	8

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 77% (5-minute) to 84% (60-minute).

Table F-6. Seven-wavelength aethalometer BC data completeness values for Bethel Island.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-470	25,799	25,799	100%	20,350	79%	3377	210	1862
5-min	520	25,799	25,799	100%	19,632	76%	4095	210	1862
5-min	590-950	25,799	25,799	100%	20,349	79%	3377	211	1862
60-min	370-470	2150	2150	100%	1794	83%	314	32	10
60-min	520	2150	2150	100%	1730	80%	378	32	10
60-min	590-950	2150	2150	100%	1794	83%	314	32	10

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 76% (520 nm 5-minute) to 83% (all wavelengths but 520 nm 60-minute).

Table F-7. Seven-wavelength aethalometer BC data completeness values for Corcoran.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-520	18,002	18,002	100%	15,350	85%	53	5	2594
5-min	590	18,002	18,002	100%	15,067	84%	336	5	2594
5-min	660-950	18,002	18,002	100%	15,334	85%	55	19	2594
60-min	370-520	1501	1501	100%	1465	98%	5	14	17
60-min	590 nm	1501	1501	100%	1300	87%	169	15	17
60-min	660-950	1501	1501	100%	1462	97%	6	16	17

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 84% (590 nm wavelength 5-minute) to 98% (370 through 520 nm wavelength 60-minute).

Table F-8. Seven-wavelength aethalometer BC data completeness values for Edwards.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370	20,928	20,928	100%	16,105	77%	1982	69	2772
5-min	470	20,928	20,928	100%	15,928	76%	1986	242	2772
5-min	520-950	20,928	20,928	100%	16,101	77%	1986	69	2772
60-min	370	1745	1745	100%	1395	80%	170	12	168
60-min	470	1745	1745	100%	1376	79%	170	31	168
60-min	520-950	1745	1745	100%	1395	80%	170	12	168

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 76% (470 nm wavelength 5-minute) to 80% (all wavelengths except 470 nm 60-minute).

Table F-9. Seven-wavelength aethalometer BC data completeness values for Sacramento Del Paso.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370	36,444	36,444	100%	25,014	69%	1	167	11,262
5-min	470	36,444	36,444	100%	24,694	68%	5	483	11,262
5-min	520-950	36,444	36,444	100%	25,014	69%	1	167	11,262
60-min	370-950	3037	3037	100%	2367	78%	1	63	606
60-min	470	3037	3037	100%	2329	77%	4	98	606
60-min	520-950	3037	3037	100%	2367	78%	1	63	606

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates (see comments for the Angiola Trailer) ranged from 68% (most of the wavelengths 5-minute) to 78% (most of the wavelengths 60-minute).

Table F-10. Seven-wavelength aethalometer BC data completeness values for San Jose.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370-880	36,861	36,861	100%	29,982	81%	1	143	6735
5-min	950	25,013	25,013	100%	22,508	90%	11	126	2368
60-min	370-880	3073	3073	100%	2847	93%	1	49	176
60-min	950	2085	2085	100%	1996	96%	7	26	56

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates ranged from 81% (most wavelengths 5-minute) to 96% (950 wavelength 60-minute).

Table F-11. Seven-wavelength aethalometer BC data completeness values for Sierra Nevada Foothills.

Data Type	Wave-length (nm)	Total No. of Records	No. of Expected Records	Percent Capture ^a	No. of Valid Records	Percent Recovery ^b	No. of Suspect Records	No. of Invalid Records	No. of Missing Records
5-min	370	25,013	25,013	100%	22,513	90%	11	121	2368
5-min	470	25,013	25,013	100%	22,378	89%	10	257	2368
5-min	520-590	25,013	25,013	100%	22,509	90%	12	124	2368
5-min	660	25,013	25,013	100%	22,266	89%	13	366	2368
5-min	880	25,013	25,013	100%	22,507	90%	9	129	2368
5-min	950	36,861	36,861	100%	29,982	81%	0	144	6735
60-min	370	2085	2085	100%	1995	96%	9	25	56
60-min	470	2085	2085	100%	1986	95%	6	37	56
60-min	520-590	2085	2085	100%	1998	96%	6	25	56
60-min	660 nm	2085	2085	100%	1968	94%	9	52	56
60-min	880 nm	2085	2085	100%	1998	96%	5	26	56
60-min	950 nm	3073	3073	100%	2848	93%	0	49	176

^a. % capture = total number of records/expected records*100

^b. % recovery = number of valid records/total numbers of records

All seven wavelengths had a 100% data capture rate. Data recovery rates ranged from 81% (950 wavelength 5-minute) to 96% (several wavelengths 60-minute).

3. LOWER QUANTIFIABLE LIMIT

The LQL is the lowest concentration in ambient air that can be measured when processing actual samples. Sources of variability that influence the monitored signal at low concentrations include instrument noise and atmospheric variability. As a measure of this variability, two times the standard deviation of selected 5-minute and 60-minute data were used to estimate the LQL. The selected data were taken during periods with concentrations close to the zero and relatively stable. This is a conservative estimate of the LQL because it includes the concentration variability of the ambient air. Twelve consecutive data values were used to compute the LQL with the 5-minute data and six data values with the 60-minute data; atmospheric variation generally becomes too great after six hours to calculate a reasonable LQL. Since only half the number of data values were used in the calculation (see “N” in Equation F-1), the 60-minute LQL is expected to be higher than the 5-minute LQL, despite the “smoothing” that occurs when averaging 5-minute to 60-minute values.

The LQL is calculated as shown in Equation F-1. **Table F-12** shows both the 5-minute and 60-minute LQL for all wavelengths, as well as the specific data strings used to calculate the LQL. For the 5-minute data, only the 660 nm data LQL meets the DQO. All wavelengths for 60-minute data meet the DQO.

$$LQL \approx 2s = 2\sqrt{\frac{\sum (aeth7 - \overline{aeth7})^2}{N - 1}} \quad (F-1)$$

where:

- $\overline{aeth7}$ = mean aethalometer 7-wavelength PM_{2.5} BC concentration
- N = number of measurements
- σ = standard deviation

Table F-12. Time period used to calculate LQL, the LQL, and the corresponding mean concentration during the selected time period.

Type of data	Wavelength nm	Time Period Used in LQL Calculation	LQL ($\mu\text{g}/\text{m}^3$)	Mean ($\mu\text{g}/\text{m}^3$)
5-minute	370	12/12/00 12:10 – 13:10 PST	0.049	0.058
5-minute	470	12/12/00 12:30 – 13:30 PST	0.057	0.080
5-minute	520	12/12/00 12:10 – 13:10 PST	0.077	0.068
5-minute	590	12/12/00 12:10 – 13:10 PST	0.081	0.064
5-minute	660	1/10/01 23:00 – 1/11/01 00:00 PST	0.018	0.009
5-minute	880	12/12/00 12:00 – 13:00 PST	0.117	0.068
5-minute	950	12/12/00 13:25 – 14:25 PST	0.099	0.084
60-minute	370	2/10/01 12:00 – 18:00 PST	0.012	0.007
60-minute	470	2/10/01 12:00 – 18:00 PST	0.011	0.013
60-minute	520	2/10/01 12:00 – 18:00 PST	0.013	0.011
60-minute	590	2/10/01 12:00 – 18:00 PST	0.012	0.012
60-minute	660	2/13/01 18:00 – 2/14/01 00:00 PST	0.035	0.010
60-minute	880	2/10/01 12:00 – 18:00 PST	0.014	0.013
60-minute	950	2/10/01 12:00 – 18:00 PST	0.014	0.016

4. ACCURACY

Calibration data for the aethalometer is not available since the aethalometer cannot be calibrated in a manner similar to instruments measuring gaseous species. Validation flow checks were performed periodically on the aethalometer; these checks can be used to evaluate the accuracy of the flow through the instrument throughout the study. This technique quantifies the variability of the measured flow from the periodic flow checks. While not the true accuracy of the BC concentration measured by the aethalometer, if most of the error is assumed to be due to flow changes, this method provides a sufficient surrogate.

Accuracy can be expressed in terms of the 95% confidence interval (CI). For aethalometer measurements, the 95% CIs were calculated from the differences between the monitor's measured flow and the known flow provided by the flow checks. The 95% CI approximates the accuracy of the data as shown in Equation F-2.

$$\text{Accuracy} \approx 95\% \text{ confidence interval} = \frac{1.96 \left(\frac{s_{\text{flowcheck}}}{\sqrt{N}} \right)}{[\text{aeth7}]_{\text{flowcheck}}} \times 100\% \quad (\text{F-2})$$

where:

$$s_{\text{flowcheck}} = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

$$x = [\text{aeth}7]_{\text{flowcheck}} - [\text{aeth}7]_{\text{measured}}$$

$$\bar{x} = \frac{\sum ([\text{aeth}7]_{\text{flowcheck}} - [\text{aeth}7]_{\text{measured}})}{N}$$

$[\text{aeth}7]_{\text{flowcheck}}$ = true flow as per flow check.

$[\text{aeth}7]_{\text{measured}}$ = flow measured during flow check by the aethalometer.

Periodic flow checks were performed at all sites; Angiola Tower 100-m is used as the representative site for all 7-wavelength aethalometers operated by STI during CRAPQS. The average flow measured during flow checks, $[\overline{\text{aeth}7}]_{\text{measured}}$, was calculated by averaging the measured flows during the periodic flow checks. The 95% CIs and the number of flow checks used to estimate the CIs are provided in **Table F-13**.

Table F-13. Accuracy and number of flow check data points used for the aethalometer BC measurements at the representative site Angiola Tower 100-meter.

No. of Flow Checks Used	Accuracy
22	1.9%

5. PRECISION

Precision can be measured for the aethalometer by evaluating the variance of BC concentrations during a period of low variability, when atmospheric influence on variability is assumed to be minimal. 5-minute and 60-minute data were selected during periods of low variability, but when concentrations were well above the LQL. The precision was then evaluated by calculating the coefficient of variation (CV) during the period of low variability, as shown in Equation F-3.

$$\text{Precision} \approx \text{CV} = \frac{\sigma_{\text{measured}}}{[\overline{\text{aeth}7}]_{\text{measured}}} \times 100\% \quad (\text{F-3})$$

where:

$$\sigma_{\text{measured}} = \sqrt{\frac{\sum ([\text{aeth}7]_{\text{measured}} - [\overline{\text{aeth}7}]_{\text{measured}})^2}{N - 1}}$$

All the PM_{2.5} BC concentrations in Equation F-3 refer to the concentrations measured during the selected time period. **Table F-14** shows the precision calculated for the representative site, Angiola. At the mean concentrations noted, the precision of the 5-minute BC measurements meet the DQO at all wavelengths while the 60-minute data do not.

Table F-14. Precision, the number of data points, time period, and mean BC concentration used to calculate the precision of the 7-wavelength aethalometer at the representative site, Angiola.

Interval	Wavelength nm	No. of Data Points Used	Time Period	Mean ($\mu\text{g}/\text{m}^3$)	Precision
5-minute	370	12	12/15/00 02:25 – 03:25 PST	0.847	1.5 %
5-minute	470	12	12/15/00 02:25 – 03:25 PST	0.863	1.1 %
5-minute	520	13	11/15/00 04:15 – 05:20 PST	0.950	1.4 %
5-minute	590	12	2/4/01 15:05 – 16:05 PST	1.528	1.7 %
5-minute	660	18	1/4/01 11:10 – 12:40 PST	1.821	1.8 %
5-minute	880	17	1/4/01 11:05 – 12:40 PST	1.935	1.0 %
5-minute	950	12	1/4/01 10:40 – 11:40 PST	1.950	1.0 %
60-minute	370	6	1/2/01 12:00 – 18:00 PST	1.354	3.9 %
60-minute	470	6	1/2/01 12:00 – 18:00 PST	1.478	3.3 %
60-minute	520	6	1/2/01 12:00 – 18:00 PST	1.499	3.0 %
60-minute	590	6	1/2/01 12:00 – 18:00 PST	1.552	3.7 %
60-minute	660	6	1/2/01 12:00 – 18:00 PST	1.610	4.6 %
60-minute	880	6	1/4/01 11:00 – 17:00 PST	1.850	4.9 %
60-minute	950	6	1/4/01 11:00 – 17:00 PST	1.880	4.3 %

6. REFERENCES

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